

occasion before long to communicate to you the general results of all observations made during past years.

An equally interesting set of observations carried out by the Meteorological Bureau was the determination of areas shaken in every earthquake, together with the reductions of results during the years 1885-86—the works of which I was directed to superintend. The method followed out was almost exactly the same as that originated by Prof. J. Milne in studying “387 earthquakes in North Japan,” an epitome of which appeared some time ago in your columns. This method is briefly as follows. Observation-books furnished with directions for reporting earthquake phenomena with or without instruments were distributed, authorised by Government, among over 600 local offices throughout the empire; in fact, the earthquake observations were made a part of the duty of local officers, and the reports were transmitted free of postage. From the reports sent in by different observers thus closely stationed, maps have been made showing the disturbed area in every shock, and a summary of observations has been compiled.

The results worked out from a large number of these maps and their notes have revealed many interesting facts, and entirely confirmed the previous works of the eminent seismologist above mentioned.

The total number of earthquakes in Japan in 1885 was 482, equivalent to 1.3 shakings a day. In Tokio alone 68 shocks were registered. Earthquakes are most prevalent in Yezo, and the north and central portions of the main island along the eastern or the Pacific coast, but in provinces bordering the Japan Sea they are few, and in some places none at all; if they occur, they are generally limited to small tracts of land. Speaking of the main island in general, the range of mountains traversing through and forming the backbone of Central Nippon appears to divide it into two zones of different seismic activities. In Kiushū, Shikoku, and other islands, disturbances are comparatively small.

Most larger earthquakes originate beneath the ocean. The majority of shocks are only local. Of the whole number, 235 local disturbances were recorded, which have not extended more than 100 square miles of land area. The maximum area of one earthquake was 34,700 square miles. The aggregate area of disturbance during the year was 796,000 square miles, and taking the total area of the empire to be 1,47,000 square miles, it is equivalent to saying that the whole of Japan has been shaken 5.4 times in one year. In summer shocks are less prevalent than in winter. The earthquakes occur in groups, that is to say, when disturbances occur, they are limited within certain portions of country, not generally extending beyond these limits. Propagations of seismic waves are often stopped by mountain-chains.

Finally, I may state that we shall continue these observations in future, and I hope the results to be obtained from more years' work of this nature will be some help in throwing light on the physics of the earth's crust.

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“The Krakatō Dust-Glows of 1883-84”

IN your issue of March 25 (p. 483) the writer of the critical notice of Dr. Riggensbach's pamphlet on the above propounds a statement which, if true, is of vast importance in accounting for the subsequent optical phenomena which are supposed to have been connected with the eruption. He says: “Thus the hurling into the air of 150 cubic kilometres of volcanic dust in August 1883,” &c. Whence does he deduce this enormous quantity? M. Verbeek, in his “Krakatō,” part 1, which I have carefully perused, estimates the entire volume of ejecta (chiefly based on what fell near the spot) at only 18 cubic kilometres, and as his work is the only reliable source of information regarding the eruption with which I am acquainted, I am entirely at a loss to conceive how the 18 has been suddenly magnified into 150.

As one of the Krakatō Committee of the Royal Society, I have naturally examined the theoretical possibility of the amount of dust ejected having been sufficient to account for the optical phenomena witnessed, and have been obliged to content myself with the very modest quantity of 4 cubic kilometres out of the total 18, but if your writer's statement is correct, I am evidently at liberty to considerably augment the quantity at my disposal, and it is needless to say that this would seriously change the aspect of the question.

E. DOUGLAS ARCHIBALD

April 15

Pumice on the Cornish Coast

Is Mr. Guppy sure that the “punice” he records in NATURE for April 15 (p. 559), as found on Maenporth Beach, is the natural article? I ask because of having been accustomed to find pieces of a pumice-like stone, many light enough to float on the sea, along the Suffolk coast. This, however, is an artificial product, a sort of cinder from steamers, though it has deluded many people. It puzzled me for some time.

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Ferocity of Animals

IF your correspondent in last week's NATURE (p. 583) will treat a wild rat in the way which I described, the animal will answer his question much more effectually than I can. For while I have only words at my disposal whereby to convey any “ejective” information upon the subject, the rat will display the fact of his understanding your correspondent's intention by a thousand co-ordinated movements of a much more eloquent kind.

The paper by Mr. Lloyd Morgan in the current issue of *Mind* is merely a republication of his views as already presented in this periodical. Having replied to these views as fully as seemed to me desirable when they were first expressed, it is needless that I should now go over the same ground a second time. It will, therefore, be sufficient to refer your correspondent to the discussion between Mr. Morgan and myself, which he will find in consecutive issues of NATURE for February and March 1884.

GEORGE J. ROMANES

The Climbing Powers of the Hedgehog

I REMEMBER many years ago we kept a hedgehog on the Continent in an upper garden well walled in. There she remained for some time, until she littered four or five young in a rubbish heap in a corner. The young having grown, and being able to move about, she and her whole brood disappeared. Her only way was over a wall four or five feet high, on which she left traces, but the young could not have been able to climb this, and she must have carried them.

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ON THE LAW OF THE RESISTANCE OF THE AIR TO THE MOTION OF PROJECTILES

IN my experiments made to determine the resistance of the air to the motion of projectiles, it was assumed that this resistance followed *some law* producing a gradual change in the velocity, and consequently that the times occupied by the shot in passing over a succession of equal spaces would admit of being differenced. This method of proceeding gave the required result in the form of a coefficient K_v of v^3 , in terms of the second and higher differences of time above referred to, when the time was expressed in seconds to five places of decimals. So long as this value of K remains constant, the resistance of the air varies as the *cube* of the velocity. The first results obtained were published in a note in the *Phil. Trans.* for 1868, p. 441. The experiments were afterwards more carefully calculated, and given in detail in the Reports published by Government in 1870. In using these results to calculate general tables for space and time, for cases where the projectile could be supposed to move approximately in a straight line, and free from the action of gravity, the corrected mean values of K_v were used, and made to vary with the corresponding velocity v . And in my “Treatise on the Motion of Projectiles” (1873), the *cubic* law of resistance was used for the purposes of calculation, so that for those velocities where K varied it was necessary to divide the trajectory into such small arcs that, throughout each arc, the average value of K could be used without sensible error. This treatment of the question rendered it unnecessary for me to attempt to express the law of resistance according to powers of v for all practical velocities. But from the results of my experiments for velocities between 900 and 1700 f.s., I remarked

that "the resistance of the air may be considered to vary roughly as the *sixth* power of the velocity for velocities 900-1100 f.s., to vary as the *third* power for velocities 1100-1350 f.s., and to vary as the *second* power for velocities above 1350 f.s. (*Proc. R.A. Inst.*, September 1871).

Further experiments were made in 1878-80, which furnished the values of K for velocities from 100 to 2800 f.s., as published in Reports, 1879 and 1880.

I now propose to express the resistance of the air to the motion of ogival-headed shot ($1\frac{1}{2}$ diam.) in terms of v^2 , v^3 , and v^6 , according to the values of v . The Newtonian law of retardation is given by $-\frac{d^2}{dt^2}k\left(\frac{v}{1000}\right)^2$; the cubic

law by $-\frac{d^3}{dt^3}K\left(\frac{v}{1000}\right)^3$; and the law of the 6th power by $-\frac{d^6}{dt^6}L\left(\frac{v}{1000}\right)^6$, where d denotes the diameter of the shot in inches, and w its weight in pounds. The values of K_v used in the tables given below (I. to V.) are those given directly by experiment, as published in my Reports of 1870 and 1880, with the exception that the values of K_v for velocities between 1080 and 1580 f.s. have been increased by 0.68 per cent., to render the density of the air uniform throughout.

The points of division in these tables are somewhat arbitrary, and if they should be passed a little either way the practical error will not be large. Capt. Ingalls, of the U.S. First Artillery, has deduced very similar coefficients from my experiments, which he has published in his "Exterior Ballistics" (1885).

In another place I have shown (*Proc. of the R.A. Inst.*, 1885) how K may be corrected: (1) for density of the air, by the introduction of a factor τ ; (2) for steadiness of the shot by a factor σ ; and (3) for a different form of head, by a factor κ . The corrected value of K thus becomes $K\tau\sigma\kappa$. And the same form of correction will apply to the coefficients k and L .

It must be remarked that the values of K for high velocities were derived from the motion of shot fired at low elevations. Consequently, in calculating ranges for comparison with experimental ranges, &c., the best agreement may be expected for low elevations of 1° to 4° or 5° . But when the muzzle velocity is high and the elevation considerable, there are several disturbing causes to be considered.

The elongated projectile has a tendency to preserve the parallelism of its axis, but this soon becomes inclined to the direction of motion of its centre of gravity, and hence arises a lateral pressure from below, which gives rise to a gyratory motion of the shot. The effect of this upon the shot is to increase the resistance of the air, to give a lateral "drift," and probably a still greater vertical "drift," because the *first* lateral disturbing pressure is from below.

When the projectile rises to a great height the density of the air decreases, and the resistance of the air is consequently diminished.

The direction of the initial motion of a shot is commonly not that in which the gun is pointed, but is affected by an error called the "jump."

All these errors tend generally to increase the range, except that, when the axis of the shot is oblique to the direction of motion, the resistance is increased. But it is evident that the direction of the axis of the shot does not differ much from the direction of the tangent to the trajectory, because the holes made in targets appear practically circular.

And, further, guns have different shooting qualities, and it is said that two guns of the same type do not shoot alike. One gun may be superior to another for one charge and be inferior for a different charge, as our experiments clearly showed. I mention these matters to show that we cannot expect an *exact* agreement in all cases between calculation and experiment.

TABLE I.—RESISTANCE $\propto v^3$

v f.s.	Experi- mental K_v	$vK_v = k_v$ 1000	Error	v f.s.	Experi- mental K_v	$vK_v = k_v$ 1000	Error
430	132.9	57.1	- 4.2	670	100.2	67.1	+ 5.8
440	132.9	58.5	- 2.8	680	98.4	66.9	+ 5.6
...	...	...	...	690	96.9	66.9	+ 5.6
460	138.2	63.6	+ 2.3	700	87.7	61.4	+ 0.1
470	147.0	69.1	+ 7.8	710	81.8	58.1	- 3.2
480	164.6	79.0	+ 17.7	720	83.6	60.2	- 1.1
...	...	...	...	730	72.8	53.1	- 8.2
530	117.2	62.1	+ 0.8	740	78.8	58.3	- 3.0
540	113.1	61.1	- 0.2	750	83.1	62.3	+ 1.0
550	109.5	60.2	- 1.1	760	83.9	63.7	+ 2.4
560	97.4	54.5	- 6.8	770	85.7	66.0	+ 4.7
570	101.9	58.1	- 3.2	780	81.0	63.2	+ 1.9
580	95.9	55.6	- 5.7	790	72.1	57.0	- 4.3
590	109.0	64.3	+ 3.0	800	61.4	49.1	- 12.2
600	111.6	67.0	+ 5.7	810	60.7	49.1	- 12.2
610	107.6	65.6	+ 4.3	820	66.5	54.5	- 6.8
...	...	...	...	830	75.5	62.7	+ 1.4
650	94.5	61.4	+ 0.1	840	75.1	63.1	+ 1.8
660	97.0	64.0	+ 2.7	850	70.7	60.1	- 1.2

Mean value of $k = 61.3$ for velocities under velocity 850 f.s.

As it was impossible to carry out experiments for velocities below 430 f.s. in the usual way, special experiments were made with elevations of 45° and muzzle velocities 420-140 f.s. The ranges and times of flight were calculated on the supposition that the above law held for velocities below 430 f.s. (Final Report, pp. 7, 48, 49). As the agreement between calculation and experiment was satisfactory, it was concluded that the above found law was good for velocities 100 to 850 f.s.

TABLE II.—RESISTANCE $\propto v^3$

v f.s.	Experi- mental K_v	Error	v f.s.	Experi- mental K_v	Error
850	70.7	- 3.7	950	76.1	+ 1.7
860	68.6	- 5.8	960	73.8	- 0.6
870	65.2	- 9.2	970	73.6	- 0.8
880	65.7	- 8.7	980	73.5	- 0.9
890	75.3	+ 0.9	990	74.6	+ 0.2
900	81.6	+ 7.2	1000	74.6	+ 0.2
910	79.7	+ 5.3	1010	74.6	+ 0.2
920	77.6	+ 3.2	1020	74.2	- 0.2
930	76.3	+ 1.9	1030	75.1	+ 0.7
940	73.3	- 1.1	1040	84.0	+ 9.6

Mean value of $K = 74.4$ between velocities 850 and 1040 feet per second.

TABLE III.—RESISTANCE $\propto v^6$

v f.s.	Experi- mental K_v	$\left(\frac{1000}{v}\right)^3 K_v = L_v$	Error
1040	84.0	74.7	- 4.5
1060	92.1	77.3	- 1.9
1080	106.0	84.1	+ 4.9
1100	107.2	80.5	+ 1.3

Mean value of $L = 79.2$ between velocities 1040 and 1100 feet per second.

TABLE IV.—RESISTANCE $\propto v^3$

v f.s.	Experi- mental K_v	Error	v f.s.	Experi- mental K_v	Error
1100	107.2	- 1.6	1220	110.3	+ 1.5
1120	105.0	- 2.8	1240	108.7	- 0.1
1140	109.0	+ 0.2	1260	109.4	+ 0.6
1160	109.7	+ 0.9	1280	111.2	+ 2.4
1180	109.5	+ 0.7	1300	109.3	+ 0.5
1200	106.5	- 2.3			

Mean value of $K = 108.8$ between velocities 1100 and 1300 feet per second.

TABLE V.

v f.s.	Experi- mental K_v	$\frac{vK_v}{1000} = k_v$	Error	v f.s.	Experi- mental K_v	$\frac{vK_v}{1000} = k_v$	Error
1300	109.3	142.1	+0.6	2120	67.6	143.3	+1.8
1320	108.0	142.6	+1.1	2130	67.8	144.4	+2.9
1340	106.3	142.4	+0.9	2140	67.5	144.5	+3.0
1360	105.6	143.6	+2.1	2150	67.5	145.1	+3.6
1380	105.9	146.1	+4.6	2160	67.1	144.9	+3.4
1400	105.0	147.0	+5.5	2170	67.0	145.4	+3.9
1420	104.4	148.2	+6.7	2180	67.0	146.1	+4.6
1440	103.2	148.6	+7.1	2190	67.0	146.7	+5.2
1460	101.2	147.8	+6.3	2200	66.9	147.2	+5.7
1480	99.1	146.7	+5.2	2210	66.9	147.8	+6.3
1500	98.0	147.0	+5.5	2220	66.9	148.5	+7.0
1520	94.7	143.9	+2.4	2230	66.9	149.2	+7.7
1540	93.0	143.2	+1.7	2240	66.9	149.9	+8.4
1560	92.7	144.6	+3.1	2250	66.8	150.3	+8.8
1580	91.9	145.2	+3.7	2260	66.8	151.0	+9.5
1600	90.4	144.6	+3.1	2270	66.8	151.6	+10.1
1610	89.2	143.6	+2.1	2280	67.7	154.4	+12.9
1620	87.9	142.4	+0.9	2290	66.9	153.2	+11.7
1630	86.7	141.3	-0.2	2300	66.9	153.9	+12.4
1640	84.1	137.9	-3.6	2310	67.0	154.8	+13.3
1650	84.2	138.9	-2.6	2320	66.1	153.4	+11.9
1660	84.6	140.4	-1.1	2330	64.4	150.1	+8.6
1670	84.9	141.8	+0.3	2340	64.6	151.2	+9.7
1680	85.1	143.0	+1.5	2350	64.6	151.8	+10.3
1690	84.8	143.3	+1.8	2360	64.6	152.5	+11.0
1700	84.5	143.7	+2.2	2370	63.8	151.2	+9.7
1710	84.8	145.0	+3.5	2380	63.7	151.6	+10.1
1720	82.8	142.4	+0.9	2390	61.0	145.8	+4.3
1730	81.5	141.0	-0.5	2400	59.8	143.5	+2.0
1740	80.1	139.4	-2.1	2410	59.2	142.7	+1.2
1750	78.3	137.0	-4.5	2420	57.1	138.2	-3.3
1760	78.3	137.8	-3.7	2430	57.1	138.8	-2.7
1770	80.5	142.5	+1.0	2440	54.5	133.0	-8.5
1780	79.7	141.9	+0.4	2450	52.8	129.4	-12.5
1790	79.2	141.8	+0.3	2460	52.2	128.4	-13.1
1800	78.8	141.8	+0.3	2470	52.2	128.9	-12.6
1810	74.7	135.2	-6.3	2480	52.3	129.7	-11.8
1820	74.9	136.3	-5.2	2490	52.3	130.2	-11.3
1830	74.7	136.7	-4.8	2500	52.3	130.8	-10.7
1840	74.7	137.4	-4.1	2510	52.4	131.5	-10.0
1850	74.7	138.2	-3.3	2520	52.4	132.0	-9.5
1860	74.5	138.6	-2.9	2530	52.5	132.8	-8.7
1870	72.3	135.2	-6.3	2540	52.6	133.6	-7.9
1880	73.3	137.8	-3.7	2550	52.6	134.1	-7.4
1890	74.5	140.8	-0.7	2560	52.7	134.9	-6.6
1900	71.5	135.9	-5.6	2570	52.7	135.4	-6.1
1910	71.6	136.8	-4.7	2580	53.4	137.8	-3.7
1920	69.9	134.2	-7.3	2590	53.5	138.6	-2.9
1930	69.5	134.1	-7.4	2600	53.6	139.4	-2.1
1940	69.0	133.9	-7.6	2610	53.6	139.9	-1.6
1950	69.4	135.3	-6.2	2620	53.7	140.7	-0.8
1960	69.6	136.4	-5.1	2630	53.8	141.5	-0.0
1970	69.2	136.3	-5.2	2640	51.5	136.0	-5.5
1980	68.4	135.4	-6.1	2650	52.1	138.1	-3.4
1990	68.2	135.7	-5.8	2660	52.0	138.3	-3.2
2000	68.3	136.6	-4.9	2670	52.0	138.8	-2.7
2010	68.3	137.3	-4.2	2680	52.0	139.4	-2.1
2020	68.4	138.2	-3.3	2690	52.0	139.9	-1.6
2030	68.2	138.4	-3.1	2700	51.9	140.1	-1.4
2040	68.5	139.7	-1.8	2710	51.9	140.6	-0.9
2050	68.4	140.2	-1.3	2720	51.9	141.2	-0.3
2060	67.7	139.5	-2.0	2730	51.9	141.7	+0.2
2070	67.8	140.3	-1.2	2740	51.9	142.2	+0.7
2080	68.0	141.4	-0.1	2750	51.9	142.7	+1.2
2090	68.2	142.5	+1.0	2760	51.9	143.2	+1.7
2100	67.9	142.6	+1.1	2770	52.5	145.4	+3.9
2110	67.8	143.1	+1.6	2780	52.5	146.0	+4.5

Mean value of $k = 141.5$ for velocities 1300 to 2780 feet per second.

I have recently calculated some ranges of elongated shot for low elevations, starting with a m.v. of 1900 f.s., allowing 6' for "jump." The following are the results obtained:—

		Elevation			
	1°	2°	3°	4°	
Experimental range...	1086	1811	2400	2917	yards
Calculated range ...	1049	1814	2392	2896	„
Difference ...	- 37	+ 3	- 8	- 21	„

In the Final Report (pp. 43-45) will be found calculated ranges for comparison with range tables, both English and German, for upwards of 120 ranges fired with muzzle velocities below 800 f.s. Taking the best of the English comparisons where the m.v. was 751 f.s.:—

	Elevation						
	5°	10°	15°	20°	25°	30°	35°
Exp. range...	978	1788	2467	3000	3467	3813	4000 yds.
Calc. ,, ...	973	1780	2462	3027	3473	3804	4013 ,,
Difference ...	- 5	- 8	- 5	+ 27	+ 6	- 9	+ 13 ,,

The worst was for a m.v. of 628 f.s.:—

	Elevation						
	5°	10°	15°	20°	25°	30°	35°
Exp. range...	691	1236	1767	2231	2683	3017	3194 yds.
Calc. ,, ...	698	1290	1805	2242	2593	2858	3037 ,,
Difference ...	+7	+54	+38	+11	-90	-159	-157 ,,

The best German comparison was with a m.v. of 705.4 f.s.:—

	Elevation					
	5°	10°	15°	20°	25°	30°
Exp. range...	875	1598	2221	2729	3139	3452 yds.
Calc. ,, ...	857	1591	2214	2730	3143	3449 ,,
Difference ...	-8	-7	-7	+1	+4	-3 ,,

The worst was for a m.v. of 774.3 f.s.:—

	Elevation					
	5°	10°	15°	20°	25°	30°
Exp. range...	1020	1900	2659	3274	3745	4130 yds.
Calc. ,, ...	1028	1878	2590	3181	3641	3987 ,,
Difference ...	+8	-22	-69	-93	-104	-143 ,,

The calculations were all made for the English projectiles where $d^2 \div w = .5616$, while for the German projectiles $d^2 \div w = .5785$. If the latter value could have been conveniently used for the German ranges, &c., the calculated ranges would have been slightly reduced, which would generally have given a still better agreement between experiment and calculation.

Since the publication of my Final Report (1880) several pamphlets treating of the resistance of the air have been issued from the private printing press of M. Krupp. The main object seems to have been to persuade the world that the Krupp system entails a lower resistance to the shot than that encountered by the English system. The difference, if any, appears due to the more pointed form of the Essen projectile, and to the lower density of the air adopted. In general no sufficient explanation is given of the particulars of the experiments made. But in the paper (xxx.) some details have been furnished of experiments undertaken at Meppen (1881) to try whether the resistance of the air varied as the square of the velocity for velocities above 400 m.s. Supposing this to be the case, an expression was found for λ the coefficient of resistance in terms of the velocities of the shot at two points in its course, the distance between them, &c.

Six chronoscopes were distributed in pairs—one pair being placed at A, 30 metres from the gun; another pair at B, 130 metres from the gun; and the remaining pair at C, 500, 1000, &c., metres from the gun. The experiments were arranged in groups. We will examine group 3, formed of rounds 7, 8, 9, and 10. The mean velocity at A was stated to be 900.1 m.s.; at B, 853.2 m.s.; and at C, 438.1 m.s. Taking the range AC, the value of $\lambda 10^6$ was found 3.585; and the range BC gave 3.700; so that the mean of the two was 3.64. The

mean value of $\lambda 10^6$ finally adopted was 3.66, differing very little from the above result.

But if we examine the matter more closely we find that the velocities for round 9, given by the two chronographs at *A* were 907.4 and 887.2 m.s., showing a difference of 20.2 m.s., or 66.3 f.s.; and for round 10 there was a difference in the measured velocities at *B* of 19.4 m.s., or 63.6 f.s.; while at *C* there was only *one* velocity measured for all four rounds, by one instrument; so that the determination of the value of λ in both the above cases was made to depend upon one solitary velocity, measured by an instrument manifestly unreliable. But at both *A* and *B* the velocity adopted was an average of the results of eight measured velocities. Consequently these velocities at *A* and *B* may be expected to give a trustworthy value of λ over range *AB*, if the experiment be of any importance. Substituting we find $\lambda 10^6 = 2.58$, something very different from its adopted value 3.66. So that, according to this group 3, the Newtonian law of resistance holds for velocities between 900 and 438 m.s., and for velocities between 853 and 438 m.s., but not for velocities between 900 and 853 m.s. ! Group 2 is still more inconsistent.

Gen. Mayevski is also the author of an attempt to express the laws of the resistance of the air to elongated projectiles from extensive experiments said to have been made at Meppen in 1881. The projectiles were more pointed, and the standard density of the air adopted was less than those used in England. Capt. Ingalls, having reduced Gen. Mayevski's coefficients to English measures for convenience of comparison, remarks, "It will be seen that these coefficients are less than the corresponding coefficients derived from Bashforth's values of K , given above. This is undoubtedly due to the different forms of projectiles used in the two series of experiments, and particularly to the difference in the shapes of the heads" (p. 21). My values of K were derived from about 350 rounds, each of which in general furnished from 8 to 10 consistent records, and gave numerous values of K by the help of a single chronograph. And the values of K used in the above tables are the means of 40, 30, 20, 10, &c., independent determinations of K for each velocity. Beyond a doubt they express accurately the average results of the rounds fired.

Although the shooting of recent guns is said to have been improved, it is doubtful whether the coefficients of resistance will require any sensible reduction on that account for long ranges. For, as we have seen, however steady may be the initial motion of an elongated shot, the lateral action of the air must soon set up a gyratory motion of the shot, and therefore the axis of the shot must become oblique to the direction of motion. And we are told that a slight initial unsteadiness of the shot becomes corrected, so that it steadies down in its flight. This we might expect from the nature of the action of the air on an elongated projectile rotating about its axis, which tends to place the axis approximately in the direction of the motion of the shot. But, if it should be found necessary to reduce the coefficient of resistance, this, as I have said, can be effected by writing $K\sigma$ instead of K , where σ is less than 1. But inasmuch as we have to use $\frac{d^2}{dw} \times K\sigma = \frac{d^2}{w\sigma} \times K$, we must first calculate the value of $\frac{d^2}{w\sigma}$, and then use the tabular numbers in the usual manner. F. BASHFORTH

PLANTS CONSIDERED IN RELATION TO THEIR ENVIRONMENT

THAT great differences of constitution are to be found among plants is at once evident—differences affecting internal structure, external form, and habit of life.

Those of structure and form at first seem likely to be correlated, and no doubt such relation to a large extent does obtain, but still it is not at all exact, differences of form occurring between plants whose internal structure closely agrees. The study of the environment of the particular plant enables us to see that this must be taken into account in tracing the changes that have made it what it is, each plant having a power of adaptation to circumstances which determines the form which it assumes, which modifies, though with extreme slowness, its internal structure, and which leads in course of time to the recognition of new species.

Looking at plants from this point of view, we notice at once great differences between those which flourish in water and those whose home is on land. These, again, show diversities between those whose habit is terrestrial and those which are epiphytic, while others are noticeable whose habit of life is more or less completely parasitic, and whose constitution and structure are much modified in consequence.

A typical land plant will be seen to consist of a stem, branching continually, bearing a variable but usually very large number of leaves, and continuous below with a root or system of roots embedded in the soil. The stem will be characterised by a great development of wood, rigidity being thus secured. The leaves will be noticeable especially for their great extent of surface in relation to their bulk, and will show, generally on their under surfaces, though very frequently on both, a large number of stomata. The roots will be woody, like the stem, and towards their ultimate terminations will be found to bear a varying number of delicate root hairs, by means of which they are enabled to discharge their special function of absorption of water.

This plan of construction is considerably deviated from by plants whose habit is aquatic. The stiffness so essential to a land plant, which has to resist storms of wind, is not at all essential to a water one, which has rather to adapt itself to varying currents of water. More flexibility, and that of a rather different kind, is needed by the stem. We find, consequently, that the rigidity of an aquatic plant is mainly arrived at by the development of turgid parenchymatous tissue containing typically large intercellular spaces, while the woody tissue largely disappears. The intercellular spaces in most cases form a very elaborate system, as may be seen on examining the petioles of the large white water-lily (*Nymphaea alba*), the stem of the common mare's-tail (*Hippuris*), or the whole plant of different species of *Potamogeton*. The number of the fibro-vascular bundles is much less than would be the case in the stem of a land plant of similar dimensions, but the most noticeable difference is the relatively much smaller amount of woody tissue in each bundle. This difference of internal constitution may be connected also with a functional difference associated with the environment. The woody tissue of a plant is concerned with the transmission of water upwards from the roots to the leaves. In the case of an aquatic plant this is not needed to anything like the extent to which it is in an ordinary tree, and hence a further reason for the disappearance of woody elements. Nor is it only the stem which has been affected by the habitat. The character of the root will be found to vary. This is best seen in noticing the effect of allowing the root of an ordinary land plant to come into contact with a quantity of water. By its constitution it is fitted to absorb only the hygroscopic water surrounding particles of soil. The first effect of the contact with excess of water is to cause the root to perish; but after a time new roots are developed which can utilise the moisture they now are in contact with, and which in turn are unable to avail themselves of the hygroscopic water which before was necessary. Both kinds of roots may be seen sometimes on plants which have been growing close to pipe-drains, some having penetrated the